Highly Dynamic Testing

Real-time modeling of a permanent magnet electrical machine for ECU functional validation applications

As part of a hybrid vehicle project, VALEO's Functional Validation Laboratory in Créteil, France, developed a HIL bench to emulate a permanent magnet electrical machine. Given the very fast dynamics of the system, and the need to work on refined electrical models, VALEO decided to use a new FPGA-based modeling technology.

Hybrid Technology at VALEO

VALEO Power Electrical System is a section of the PowerTrain Systems Business Group of Valeo. It has been very successful in providing innovative hybrid technologies which have been adopted by OEMs. When developing hybrid and mild hybrid products, VALEO faces the major challenge of designing, developing, and validating the control software for the machines they manufacture.

Designing and Evaluating Control Software

The software is implemented on electronic control units (ECUs), which need to be tested after the programming phase. The control strategies and the related software are tested in several steps. Depending on the stage in the development cycle, HIL (hardware-in-the-loop) tests are performed either by the ECU connected to the model of the permanent magnet electrical machine (PMEM) or by the ECU connected to the real PMEM. The advantage of using simulation is that control algorithms can be evaluated in any states or scenarios, including ones that are very difficult to replicate in the real world (destructive tests, tests outside the working range, robustness analyses, etc.), not to mention the cost saved by avoiding real-world tests.

Functional Validation of Hybrid Drives

For many years now, VALEO Power Electrical System, including ourselves in the Functional Validation group, have used HIL benches to evaluate or validate products with regard to the production code on the ECUs.

Figure 1: One of the electric motors that were simulated with the XSG Electric Component Library.

> "The openness and flexibility of the dSPACE E-drives solutions were ideal for the punctual completion of our mild hybrid project."
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> *Stéphane Fourmy, VALEO Power Electrical System*

With the growing trend towards more hybrid technology in vehicles, we are running an increasing number of new projects. These involve machines with more and more power, and requiring even more complex control algorithms and strategies that need to be developed and validated. To meet market requirements, not only does the complexity of the systems increase; time-to-production also remains inflexible or is even shortened, necessitating constant improvements in development processes. The challenge faced by our Functional Validation Laboratory in VALEO Power Electrical System is to give R&D teams a validation and evaluation solution whatever the complexity of the new technology.

Mild Hybrid Development Project

The control strategies on a new PMEM needed to be developed and validated for a project in the mild hybrid range. VALEO also had the responsibility of providing the production code for the ECU controlling the electrical machine, the inverter and the resolver. Because of the power involved, the new type of machine, and changes to the sensors used, the project involved substantial modeling efforts. To test the code on the ECU, VALEO used hardware-in-the-loop simulation as usual.

FPGA for Quick Response Times

The fast dynamics of the system required a change in real-time HIL technology. A survey of available solutions showed that field-programmable gate arrays (FPGAs) would provide very fast response times. It also revealed that major progress had been made on facilitating FPGA programming for modeling and simulation purposes. Solutions enabling fast and easy programming were considered the key to success. We then compared avail-

Figure 2: Configuration of a hybrid demo vehicle of VALEO.

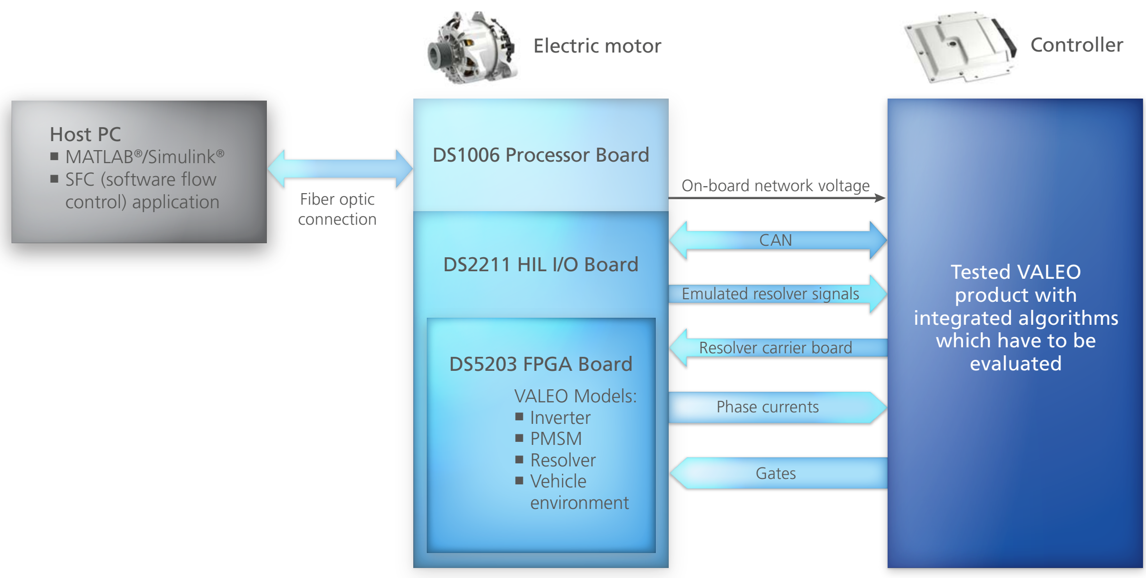

Figure 3: Structure and signals of the HIL system for emulating permanent magnetic electric machines.

able product offers. Our criteria were based on technical performance, as well as cost and development time for the bench.

HIL System for E-Drives

Because VALEO had been familiar with dSPACE tools for several years, and development time was tight, the optimal solution was a DS5203 FPGA Board from dSPACE. The overall HIL test bench includes a DS1006 Processor Board, a DS2211 HIL I/O Board, and a DS5203 installed in a PX10 Expansion Box. An external break-out box (BoB) is used to connect to the ECU in order to test its production software.

The Model of the Electrical Machine

The model of the electrical system was developed with the XSG Electric Component Library from the dSPACE Automotive Simulation Models (ASM) product family. This library builds on the XSG programming block diagram library from Xilinx® and allows Xilinx FPGAs to be programmed graphically from Simulink®. In a first step, our developers familiarized themselves with the ASM XSG Electric Component Library and one of its models – a permanent magnet synchronous machine. After hands-on training with the new ASM XSG electric component models and the FPGA board at dSPACE in Paderborn, the Functional Validation Laboratory tailored a model to VALEO's needs. Because the ASM XSG electric models are available as open XSG blocks under Simulink, it was easy to modify them with regard to current requirements or to add new blocks (for example, by varying parameters as functions of temperature and current, and introducing harmonics or deteriorations). This flexibility enabled us to adapt the model and the bench to actual project needs. The same flexibility will enable us to meet the new mechatronics validation requirements of upcoming hybrid projects for either VALEO or OEMs.

Use Scenarios for the E-Drives Test Bench

The first hybrid project with the new bench was successfully completed. The bench is already booked for a further project. Our group is currently preparing to reconfigure and adapt it to the new electrical system. We will benefit from the experience already acquired to develop a more complex model of a synchronous machine, such as a mixed-excited, double-star coupled electric machine. Thanks to the modularity of MATLAB, Simulink and the dSPACE tools, the team responsible for test bench adaptation can easily test the blocks and get results fast. That is the strength of such products. ■

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